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ABSTRACT

Available methods for collecting human factors data rely heavily on observations, interviews, and questionnaires. A need exists for other methods. The feasibility of using two-way voice-radio for this purpose was studied. The data collection methodology consisted of a human factors analyst talking from a radio base station with technicians wearing portable radio units while they worked on jobs dispersed over an area. Verbal communication probed for information on equipment problems, procedural problems, delays, and potential hazards. The concept of using radio equipment to collect human factors data was tested, using technicians performaing flight-line maintenance. Data collected by radio were compared with data collected by questionnaire. It was concluded that voice-radio is not only a feasible means of collecting human factors data in the field, but has certain advantages over questionnaires in determining hardware problems and amplifying the data-collection capability of the human factors analyst. (Author)

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A VOICE-RADIO METHOD FOR COLLECTING HUMAN FACTORS DATA

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JANUARY 1969

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FOREWORD

The research reported herein was performed during the period from September 1967 through May 1968, when the Training Research Division was assigned to the Aerospace Medical Research Laboratories, and the work was supported financially by a grant from the Commander, Colonel R. A. Yerg. On 1 July 1968, the Air Force Human Resources Laboratory was established, and the Training Research Division was transferred to this new laboratory. The study accomplished supports the Air Force Human Resources Laboratory Project 1710, "Human Factors in the Design of Training Systems," for which Dr. G. A. Eckstrand is Project Scientist, and Task 171006, "Personnel, Training, and Manning Factors in the Conception and Design of Aerospace Systems," for which Mr. M. T. Snyder is Task Scientist. The authors, Dr. W. B. Askren and Mr. N.F. Schwartz, are with the Training Research Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, and Drs. S. M. Bower and M. D. Schmid are from the University of Dayton, Dayton, Ohio.

The authors are grateful for the manpower and facilities provided by the Flight Test Maintenance Division, Wright-Patterson Air Force Base, during the field test portion of the research. The continuous participation of Mr. G. E. Manthey, during all of test phases conducted, is greatly appreciated. The assistance of the maintenance supervisors and the willingness of the technician subjects significantly aided the authors in the task of data collection. Appreciation is expressed to Messrs. W. Martin, M. Majesty, C. McLean, E. Rieck, M. Snyder, and J. Yasutake for psychometrically evaluating the data.

This report was submitted by the authors 17 October 1968.

This technical report has been reviewed and is approved.

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ABSTRACT

Available methods for collecting human factors data rely heavily on observations, interviews, and questionnaires. A need exists for other methods. The feasibility of using two-way voice-radio for this purpose was studied. The data-collection methodology consisted of a human factors analyst talking from a radio base station with technicians wearing portable radio units while they worked on jobs dispersed over an area. Verbal communication probed for information on equipment problems, procedural problems, delays, and potential hazards. The concept of using radio equipment to collect human factors data was tested, using technicians performing flight-line maintenance. Data collected by radio were compared with data collected by questionnaire. It was concluded that voice-radio is not only a feasible means of collecting human factors data in the field, but has certain advantages over questionnaires in determining hardware problems and amplifying the data-collection capability of the human factors analyst.

TABLE OF CONTENTS

SECTION		PAGE
I	INTRODUCTION	1
	1. The Problem	1
	2. Purpose of the Research	1
	3. Hardware Configuration	3
II	METHOD	6
	1. General	6
	2. Exploratory Test	6
	3. Controlled-Experimental Test	7
III	RESULTS AND DISCUSSION	10
	1. Suitable Voice-Radio Procedures	10
	2. Adaptability of Voice-Radio to an Operational Environment	10
	3. Value of Data Collected	11
	4. Specifications for an Optimum Voice-Radio System	19
	5. Additional Informal Results	19
IV	CONCLUSIONS	21
APPENDIX A	RULES FOR THE JUDGES	23
APPENDIX B	EQUIPMENT USED IN STUDY	24
REFERENCES		26

ILLUSTRATIONS

FIGURE		PAGE
1.	Concept of Human-Performance Data Collection by Voice-Radio	2
2.	Base Station	4
3.	Portable Radio Unit	5
4.	Illustration of Variance Caused by Judges	13
5.	Illustration of Variance Caused by Questions	14
6.	Illustration of Judges-Questions Interaction	15
7.	Proportion of All Responses Rated as Being of at Least Some Utility	17
8.	Illustration of Methods-Questions Interaction	18

TABLES

I.	Questions Asked Maintenance Technician Subjects	7, 8
II.	Analysis of Variance of Questions Responses	12

SECTION I

INTRODUCTION

1. THE PROBLEM

The process of collecting data regarding man's performance is a significant portion of the human factors technology. Data describing work activities of man in test and operational environments are needed to allow human factors specialists to decide, for example, whether the design of an equipment is adequate, training is thorough, personnel manning is sufficient, and task procedures are adequate and efficient.

However, the methodology available to collect such data is limited. Meister and Rabideau (Reference 2, 1965, page 224) concluded that "... most of the methods available ... are fairly unsophisticated, relying to a considerable extent on observation and interview." Other investigators (Keenan, Parker, Lenzycki, Reference 1, 1965, and Newton and Askren, Reference 3, 1968) found essentially the same thing, reporting that the three methods -- observation, interview, and questionnaire -- are the most frequently used means of collecting data concerning man's performance in system environments. Based upon these analyses of the state-of-the-art in data collection on human performance, and based upon the substantial need for data of this type, it was concluded that research oriented toward developing new data-collection methods was in order.

2. PURPOSE OF THE RESEARCH

In view of the state-of-the-art in data collection, the general purpose of the research was to study the feasibility of using two-way voice-radio as a means of collecting human performance data. A methodology titled Personnel Activity Analysis Radio System (PAARS) was conceptualized. The methodology utilized a radio base station operated by a human factors analyst, a number of small two-way radio units worn by technicans while working on the job, and voice communication between personnel to identify, interpret, and transmit desired information and data (Figure 1).

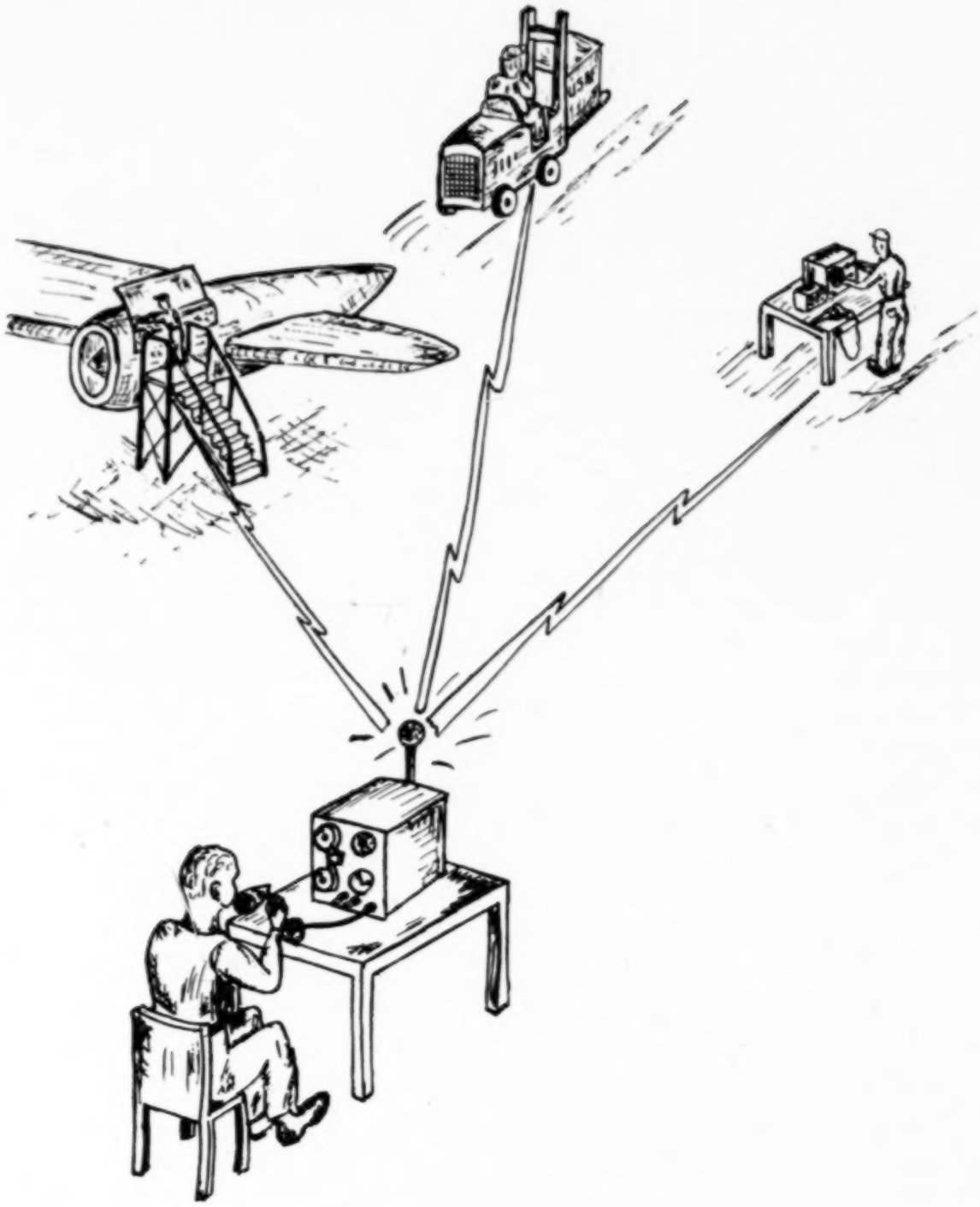

Figure 1. Concept of Human-Performance Data Collection by Voice-Radio

The specific objectives of the research were to (a) determine procedures suitable for collecting data by voice radio, (b) determine the value of the data collected by voice radio, and (c) determine adaptability to the operational environment of this method of collecting human-performance data. Value was defined as the kind, quality, and quantity of data collected. Adaptability was defined as the worker acceptance and attitude toward the data-collection process, the quantity of working personnel that could be monitored by the system, and the range and shielding limitations of the radio hardware. Finally, since the results of this study would be partially a function of the radio equipment that was selected for use, an additional objective was established: (d) develop specifications for an optimum radio data collection system.

3. HARDWARE CONFIGURATION

The concept illustrated in Figure 1 was translated into the hardware configuration illustrated in Figures 2 and 3. Figure 2 shows the base station which included a 5-watt transmitter/receiver, a selective call unit which allowed conversation with individual technicians, and a tape recorder which recorded incoming and outgoing messages. Figure 3 shows the portable radio unit. All equipment were stock items and are identified and described in Appendix B.

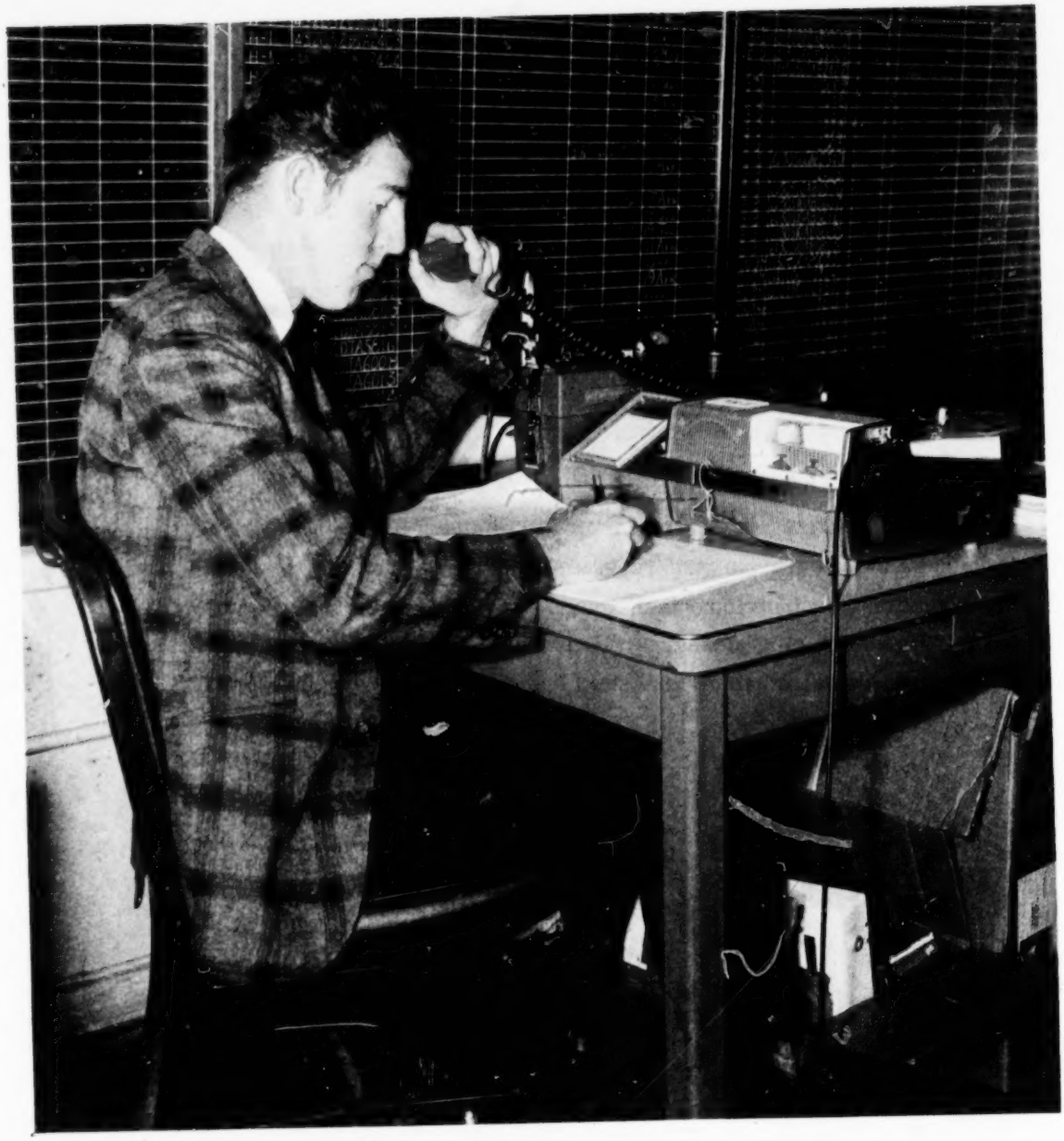

Figure 2. Base Station

Figure 3. Portable Radio Unit

SECTION II

METHOD

1. GENERAL

The diversity of objectives required a mixed approach to the research. Therefore, an exploratory test phase and a controlled-experimental test phase were conducted. The exploratory test was a limited operation which collected a small quantity of data and probed the limits of PAARS data collection capability. This test yielded data related to the research objectives of determining voice-radio procedures, adaptability of voice-radio data collection in an operational environment, and specifications for an optimum system. The controlled-experimental test was a more precise study related primarily to the research objective of the value of data collected by voice radio. It also provided some information regarding the research objectives of adaptability and optimum specifications.

2. EXPLORATORY TEST

The exploratory test studied several different data-collection procedures, investigated the maximum number of workers wearing portable radios that one human factors analyst could monitor from the base station, and studied radio equipment range and shielding problems. Radio range and shielding were checked by placing one member of the research team equipped with a portable unit in a variety of locations at a variety of distances from the base station and determining subjectively the quality of voice transmission between the unit and base station.

The maximum number of workers that could be monitored was studied by equipping various quantities of Air Force flight line maintenance technicians with portable units, and determining subjectively the overload point for voice communications about job activities between them and the base station human factors monitor. Also, two data-collection procedures were tested and subjectively evaluated. The procedures were (1), the base station called the maintenance technician on a time-sampling plan and (2), the maintenance personnel called the base station at planned work intervals.

3. CONTROLLED-EXPERIMENTAL TEST

The controlled-experimental test was designed primarily to determine the value of the PAARS method as compared with a standard human factors data-collection technique, in this case, paper-and-pencil questionnaire. The statistical model used was a three-way fixed factor analysis of variance with repeated measures on all factors (Winer, Reference 4, 1962).

a. Independent Variables and Procedures

The experimental design was implemented with data collected from six subjects under two conditions (radio and questionnaire), with each condition repeated three times. The data consisted of subject responses to the thirteen questions listed in Table I. The questions were prepared to cover the categories of equipment and tool design, safety, logistics and support, training, and work procedures.

TABLE I

QUESTIONS ASKED MAINTENANCE TECHNICIAN SUBJECTS

1.	What changes in equipment design would make it easier to maintain?
2.	What changes would make it easier to find the test points?
3.	What are the possible problems with safety on this job?
4.	What did you do to get into the equipment to be repaired?
5.	Would a new man have problems with color coding or labelling on this equipment?
6.	What were some of the delays on this job? What caused the delay(s)?
7.	What were the problems with the tools or test equipment on this job?
8.	Could you use different or more tools or test equipment on this job?
9.	Is there any special training that would help make this job easier?
10.	If you had to train a new man, what would be the most important thing for this job?

TABLE I (Continued)

11. What changes could be made in the T.O. for this job?
12. Did you see anything in the T.O. checklist that is (was) confusing?
13. What kind of mistake in procedure is most likely to happen to a new man on this job?

Experienced Air Force maintenance personnel served as subjects while they carried out their regular work assignments. These subjects normally performed several electronics maintenance jobs each day. One of these assignments, usually the first job of the day, was used as the work sample to be measured by either the radio or questionnaire condition.

During three of the test days, each subject wore a radio unit and answered the questions via radio link while at the job site. On three other test days, each subject did not wear a radio unit but reported into the PAARS base station in person at the end of the day and completed a questionnaire. This end-of-day questionnaire (EODQ) was made up of the questions listed in Table I, changed only to reflect past tense instead of present tense for some of the questions. The experimental conditions, PAARS and EODQ, were used alternately for each subject in order to minimize sequential effects.

b. Dependent Variable and Quantification

The major dependent variable was defined as richness or utility of question responses for application to human factors test and evaluation decisions. Quantification of utility was provided by judgments produced by seven judges experienced in human factors analysis, design, test, and evaluation. Each judge was instructed (Appendix A) to view at one time all responses (n = 36) to each separate question. Each response was typed on a separate sheet of paper. This set of 36 responses consisted of the responses in random order of all subjects to one question for three maintenance tasks in which the PAARS method was used, and for three tasks for which the EODQ method was used.

The judges then chose one response as most useful and one response as least useful. The respective value of most or least was then indicated by marking the appropriate extreme end of a 100-millimeter linear scale provided at the bottom of the response sheet. Given these extreme values, each judge then assigned to the remaining 34 responses, a relative value (mark on the line) ranging between the extreme values. This procedure was followed for each of the 13 questions.

At the completion of judgments, the scale markings were translated to numbers ranging from 1 (poor) to 100 (good). From each of the seven judges, there were obtained 468 scale values reflecting six subjects, six maintenance jobs, and 13 questions.

A preliminary reduction in data was performed before the analysis was carried out. Since there occurred for each subject, three instances of the PAARS method and three instances of the EODQ method, the highest value was selected from the three jobs under each method for each question. This yielded 26 values for each subject from each judge. It was upon these values that the data analysis was performed.

c. Data Analysis

Within the three-way fixed factor analysis of variance, the principle factors of interest were those of method (PAARS versus EODQ), and questions (questions 1 - 13). Study of the data regarding these factors determined the kind and quality of data collected by the two methods. The design also permitted analysis of consistency of judgments across judges (judges 1 - 7), and interactions between any two or three of the factors. The quantity of data collected was determined by count of the frequency of responses judged to be at least of some value (any rating greater than 1).

SECTION III

RESULTS AND DISCUSSION

The results are presented in relation to the research objectives of procedures suitable for voice-radio data-collection, adaptability of the voice-radio data-collection process to an operational environment, value of the data collected, and specifications for an optimum voice-radio system.

1. SUITABLE VOICE-RADIO PROCEDURES

Of the two procedures studied during the exploratory phase, the maintenance technician call-in mode was considered superior. The nature of a maintenance job, with unscheduled activity periods, demonstrated immediately the superiority of depending upon the technicians to call-in when meaningful or critical actions occurred. Sampling the work day of the technicians provided comparatively little information useful to system evaluation decisions. Therefore, the technician initiated mode was adopted for use in the controlled-experimental phase that followed.

2. ADAPTABILITY OF VOICE-RADIO TO AN OPERATIONAL ENVIRONMENT

The exploratory test phase established that this off-the-shelf radio system configuration was useful and acceptable. The clear communication range was three to four miles over open terrain, and at least one mile through multiple shielding of hangar wall and aircraft metal skin. Maintenance technicians did not react adversely to wearing and using the portable units while working on the job, although occasionally, a technician removed his radio when climbing into narrow confines of an aircraft. The human factors analyst operating the base station monitored the work of six technicians in depth, and ten technicians in a more limited way. This information influenced the design of the controlled-experimental phase to include six subjects.

3. VALUE OF DATA COLLECTED

The value of the data was determined by analysis of the technician responses to the thirteen questions. These results are described in terms of the main analysis of variance, the kind of data best collected by PAARS versus EODQ, the overall amount of data collected by radio versus questionnaire, and the overall quality of data collected by PAARS versus EODQ.

a. Main Analysis

A summary of the main analysis is shown in Table II. Variables found significant at the 0.05 level were judges, questions, and the interaction of judges with questions. These effects are illustrated in Figures 4, 5, and 6. The factors found not significant included methods (PAARS versus EODQ), methods interaction with questions, and judges interaction with methods. Thus, based on this overall analysis of the variance of quality of responses, the voice-radio method was not significantly different from the questionnaire method.

The very large F-ratio obtained for the effect of judges clearly indicates that the human factors specialists who judged the responses did not find common agreement as to their (responses) relative value. This may indicate a weakness in the judgment procedure established in this research. Perhaps a more structured criterion for judges is needed, one that relates to specific jobs within specific subsystem operations. Certainly, the large judge-variability reduced the chance of finding a significant difference between the PAARS and EODQ methods.

The significant variance of questions suggests the importance that must be attached to content, structure, and style of questions if questions are to elicit comparable quality of information.

The significant interaction of judges and questions suggests that the judges did not maintain a consistent mental set as to the value of responses, but rather shifted their concept of response utility according to the kind of question from

TABLE II

ANALYSIS OF VARIANCE OF QUESTIONS RESPONSES

Source	Degrees of Freedom	Mean Square	F Value
Methods (M) (Radio vs Questionnaire)	1	1,620	
Judges (J)	6	11,812	16.97*
Questions (Q)	12	17,206	2.47**
Subjects (S)	5	19,239	
M x J	6	498	
M x Q	12	6,023	
M x S	5	7,457	
J x Q	72	1,108	2.76*
J x S	30	696	
Q x S	60	6,956	
M x J x Q	72	384	
M x J x S	30	471	
M x Q x S	60	3,623	
J x Q x S	360	402	
M x J x Q x S	360	361	
		19,239	

* = Significant at < 0.01

** = Significant at < 0.05

which the response was obtained. Again, there is indicated a need for a more restricted criterion. For example, questions relating to training might be better assessed from a different set of rules than questions relating to work procedures, tools, and equipment.

A check on the appropriateness of the use of high-value responses in the analysis was made by analyzing median value responses. The significant effects found by this computation were identical to those of the high-value data analysis.

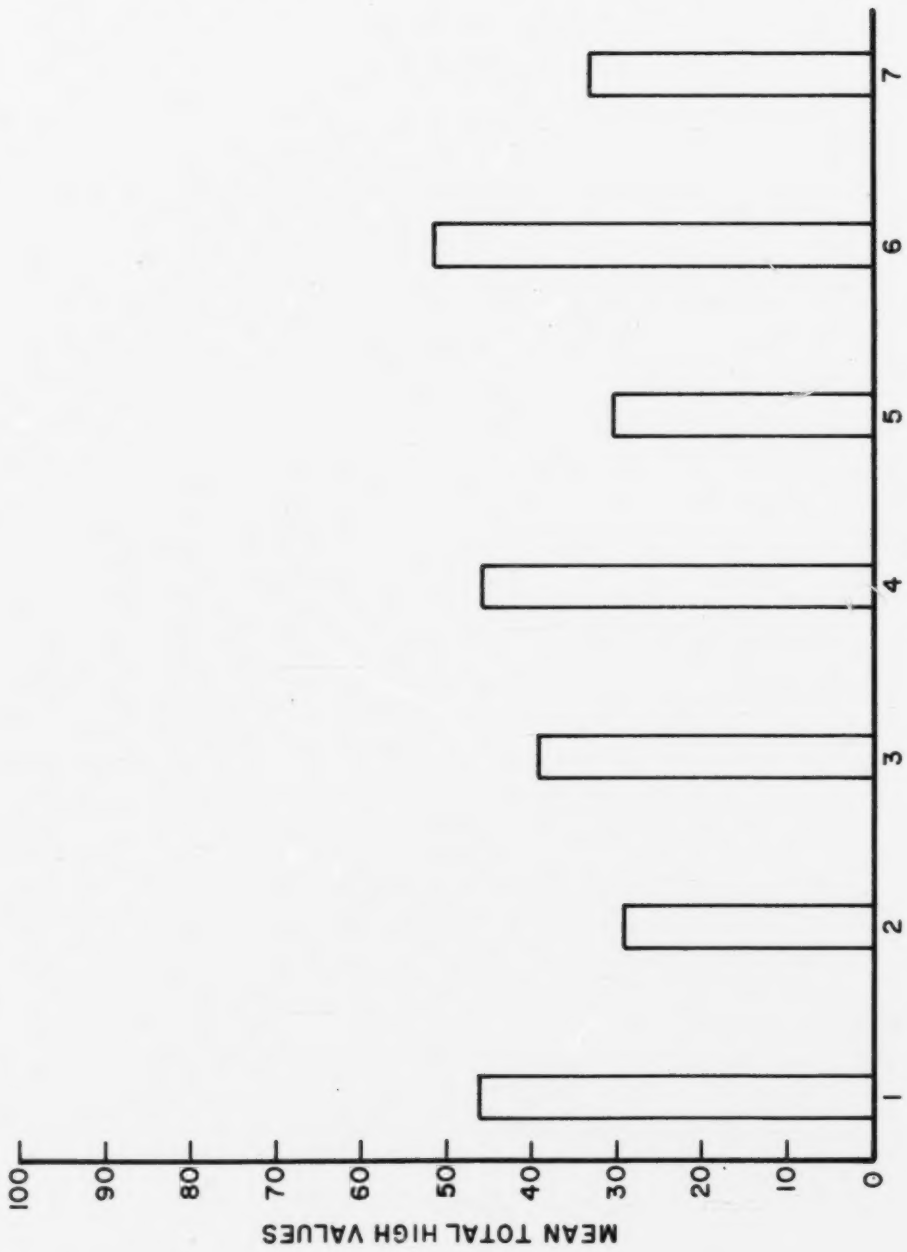

FIGURE 4. Illustration of Variance Caused by Judges

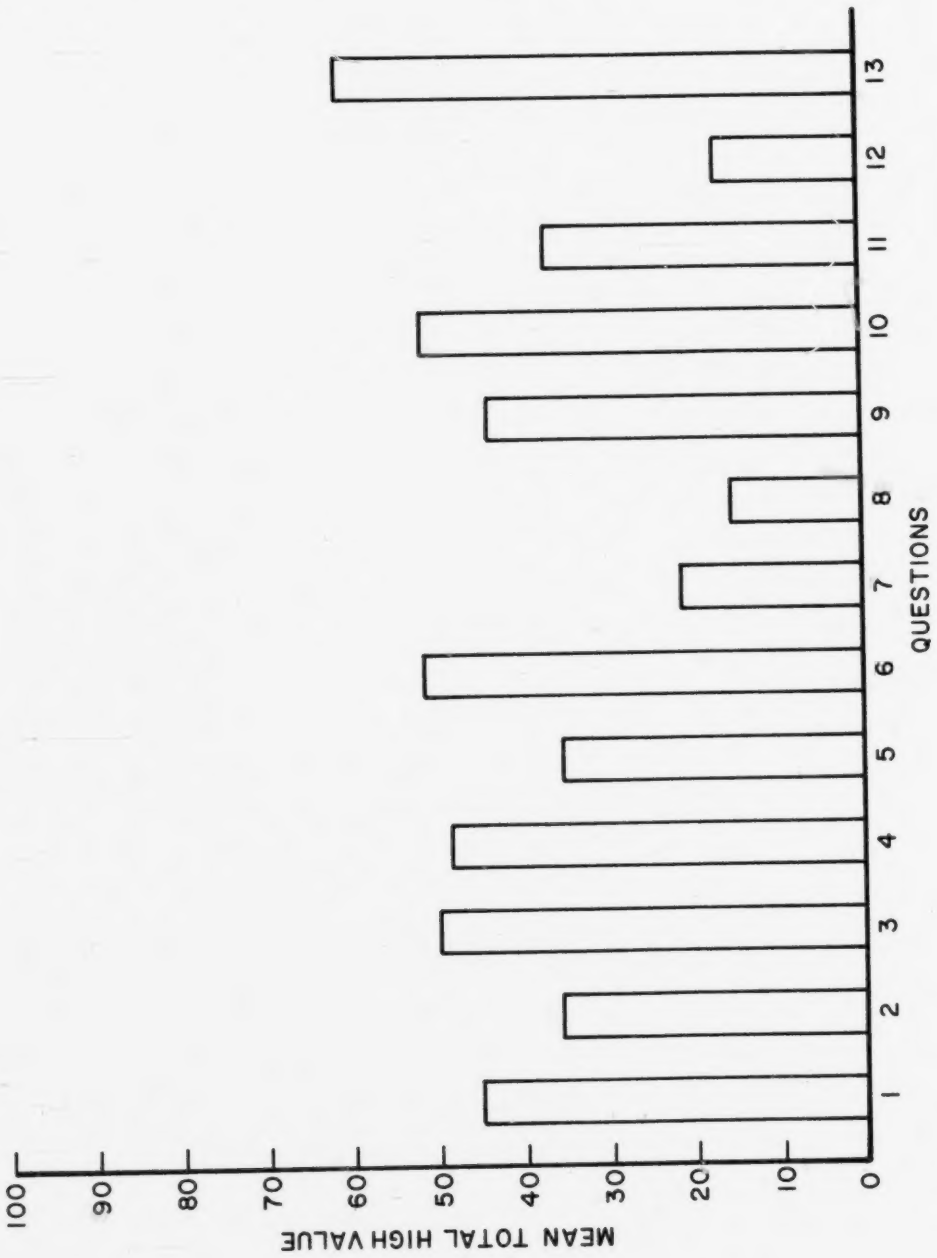

FIGURE 5. Illustration of Variance Caused by Questions

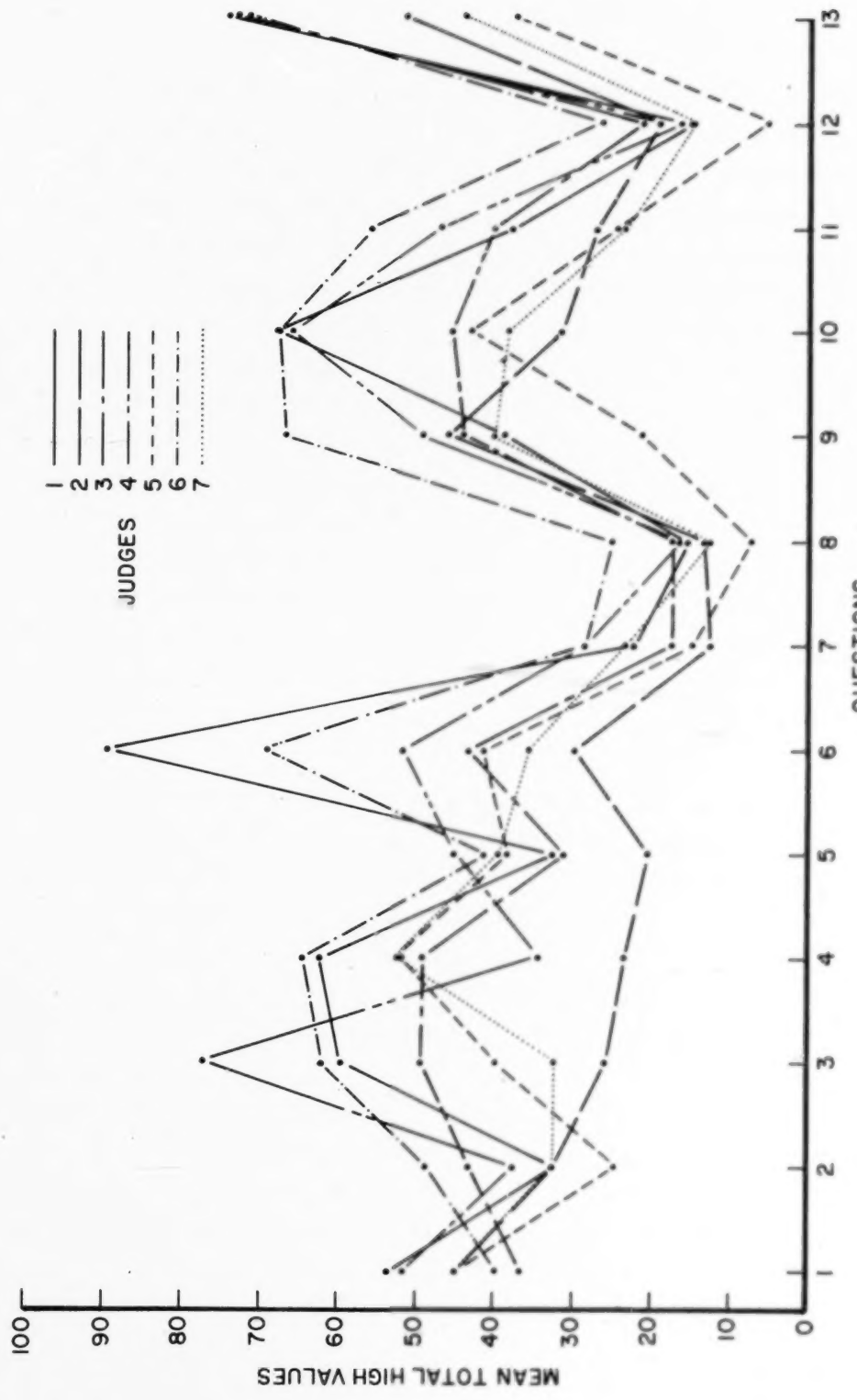

FIGURE 6. Illustration of Judges-Questions Interaction

b. Kind of Data Collected PAARS Versus EODQ

The thirteen questions used by both PAARS and EODQ methods covered a variety of topics. It was reasonable to expect that the radio method was more valuable for collecting data for some topics, and the questionnaire more valuable for others. However, the data regarding this point yielded mixed results. As indicated in the main analysis of variance of the quality of the data (Table II), there was no statistically significant interaction between questions and methods. However, Figure 7 shows that the proportion of time some useful data was obtained was significant* for the radio method for questions 1, 2, and 7, and for the questionnaire method for question 12. Thus, voice-radio seems to yield a greater quantity of data regarding equipment and tools, and the questionnaire a greater quantity regarding technical order checklists. This trend is supported by the interaction effect between methods and questions of the main analysis of variance illustrated in Figure 8. Although statistically not significant, these data show the PAARS method collecting better quality data regarding equipment and tools (questions 1, 2, 4, 5, and 7) than the questionnaire method.

c. Overall Amount of Data Collected PAARS Versus EODQ

All radio responses were judged on the average to have at least some utility 49.3% of the time. All questionnaire responses were judged on the average to have at least some utility 48.5% of the time. These results indicate that both methods were reasonably productive means of collecting information with neither practical nor statistical difference between methods.

d. Overall Quality of Data Collected PAARS Versus EODQ

Based on the 100 point rating scale used in the study, the radio method high-value responses to the questions averaged 40.8, and the questionnaire high-value responses averaged 36.5. The difference in favor of PAARS was not statistically significant. These results indicate that only moderate quality

*Chi Square value = $P < 0.05$

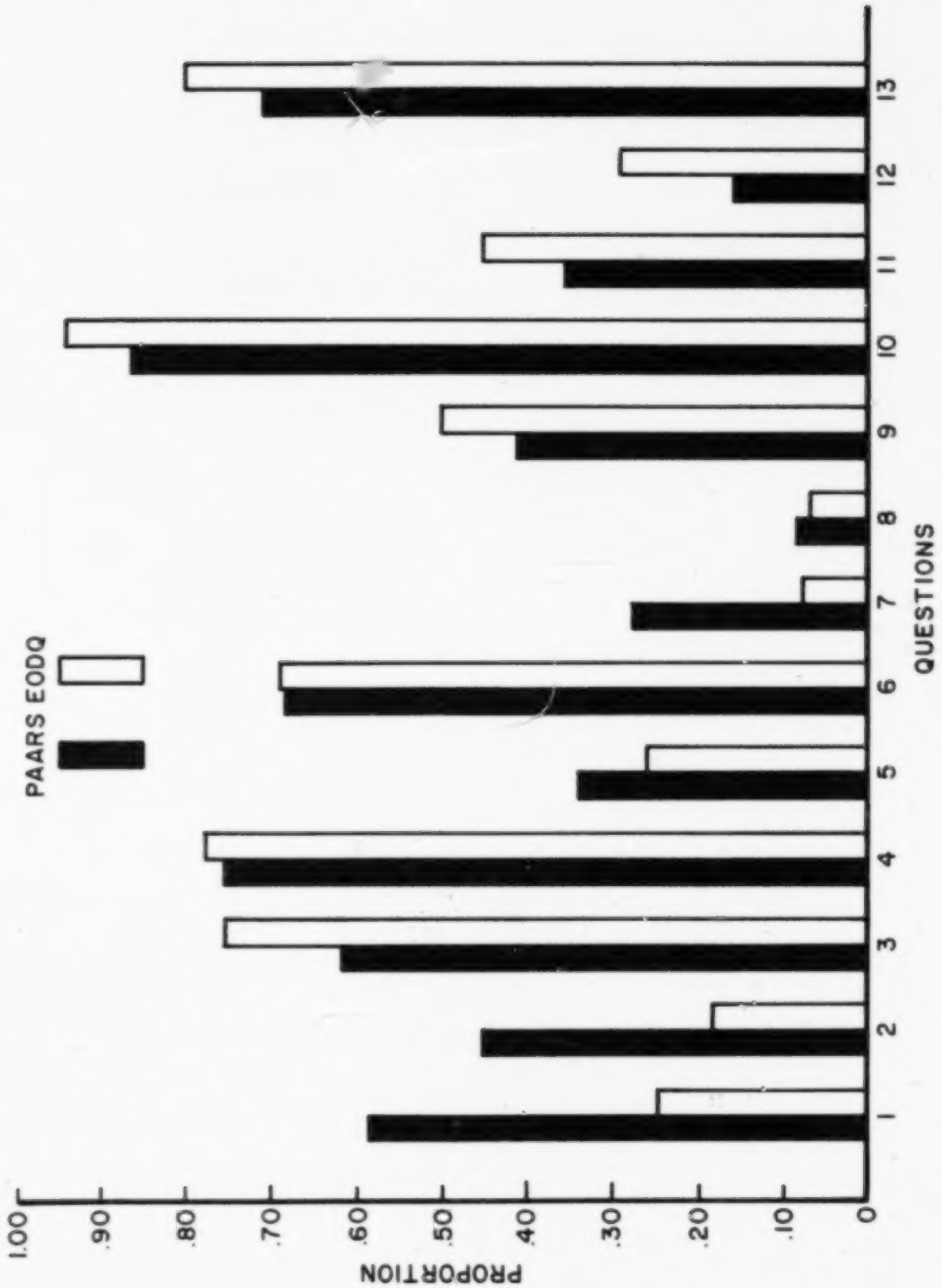

FIGURE 7. Proportion of All Responses Rated as Being of at Least Some Utility

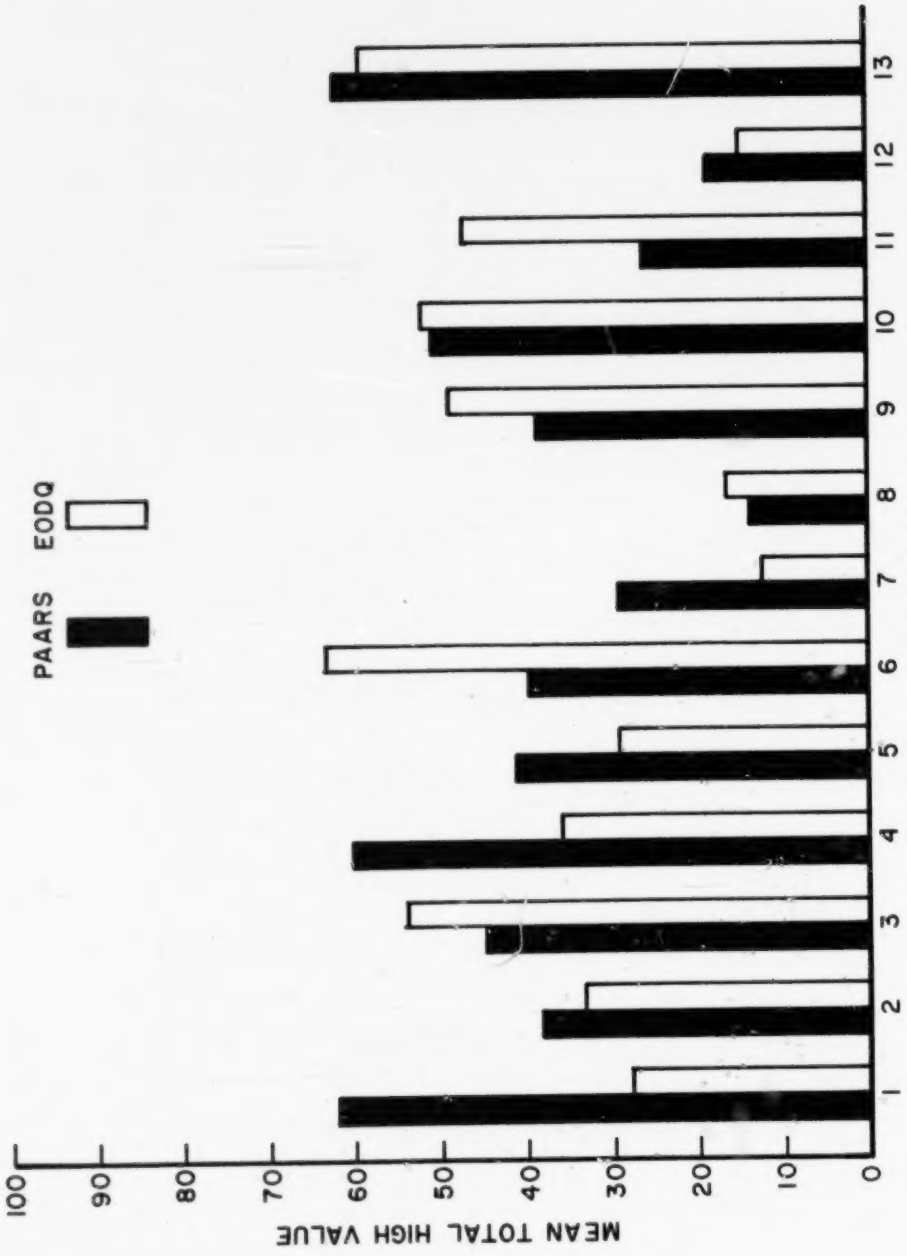

FIGURE 8. Illustration of Methods-Questions Interaction

information was collected by both methods. This suggests a real need for research in developing questions which are better suited for probing for information useful to human factors decision making.

4. SPECIFICATIONS FOR AN OPTIMUM VOICE-RADIO SYSTEM

The equipment procured off-the-shelf was generally satisfactory for the purposes of this research. A complete description of all equipment used is contained in Appendix B. However, based upon the observations made during this study, the following equipment changes would result in a better system for human factors data-collection purposes. These changes should not degrade the present equipment capability as to range, battery life, selective call, etc.

- Reduce weight and size of the personal radio unit. The design goal for the total package worn by the individual should be 25 ounces, and 25 cubic inches.

- Provide an antenna for portable units which does not require adjusting by the worker nor interfere with work activities. A concealed or self-contained antenna system is desired.

- Provide portable units with a hands-off capability for talk-listen after the unit is switched on.

- Provide the base station with a capability to make hard-line connection between transmitter-receiver and a tape recorder to permit direct recording of incoming and outgoing communications.

5. ADDITIONAL INFORMAL RESULTS

As part of the exploratory test, an experimental form was developed on which maintenance-type information was recorded. This form was filled out by the analyst at the base station, concurrent with his questioning of the individual technicians, regarding the thirteen questions listed in Table I.

The information contained on this experimental form was not quantified and summarized because the basic experiment was not designed to provide a meaningful base against which such data could be compared. It is of interest, however, to note that maintenance time was collected using the PAARS technique much more rapidly than with the direct time study method. Since tabulation of time data on the experimental form indicates that this type information can be collected using much less observer time (one human factors man at the base station can collect as much time information as six to ten time study men), it appears that there should be a very definite economic advantage in collecting all types of human factor information through the PAARS technique as compared to conventional practices.

SECTION IV

CONCLUSIONS

It is concluded that two-way voice-radio is a feasible means of collecting human performance data in operational environments. While no overall superiority was demonstrated for voice-radio versus paper-and-pencil questionnaires, the results suggest that a differential effect exists, with radio better for collecting information regarding equipment and tool problems. The radio data-collection procedure of maintenance technician initiated call-in at significant times during the work day is a fruitful method of obtaining information. The radio method was well received by the technician subjects. Voice-radio appears to offer another means of collecting human factors data in field situations, and its potential should be more fully explored. Future studies should be directed toward determining the specific data-collection uses of voice-radio and attempting to measure the cost-effectiveness, reliability, and validity of this method as compared with the more conventional techniques of interviewing, observing, and questionnaire.

APPENDIX A

RULES FOR JUDGES

The judges were briefed concerning the general purposes of the experiment, and they were alerted to the aims of Personnel Subsystem Test and Evaluation (PSTE). As a minimum, this included the recognition that PSTE is necessary to evaluate whether or not personnel subsystem activities are producing the human performance necessary to complete systems requirements, specifically, to reveal and correct deficiencies in personnel selection, training, support, technical publications, work procedures, and maintenance design problems.

Additionally, judges were informed that the PSTE data, such as they were to judge, would form the basis for making decisions and formulating reports pertaining to the PSTE factors in a man-machine system.

The judges were then presented in randomized order, 13 sets of 36 response items. The specific instructions to the judges were:

> "You are to choose one response of each set as providing maximally useful source information for PSTE. Mark this response on the extreme end of the scale at the position of "most useful." Then choose one response as minimally useful and place a mark at the extreme end of the scale at the position of "least useful." Then observe the remaining 34 response sheets of each set and determine the scale value to each of these responses relative to the responses judged as most and least useful. When you have completed the first set, arrange the second set, and repeat the above procedure, etc. Please complete each set at one sitting, however, you may interrupt your judgments between sets as you determine."

APPENDIX B

EQUIPMENT USED IN STUDY

Two kinds of equipment were used in this study: the radio communications equipment and the equipment for recording interviews. The communications equipment consisted of a receiver-transmitter with encoder unit, designated as the base station, and 10 portable receiver-transmitters plus a battery charger capable of charging all of the portable receiver-transmitters. All of the commuication units were standard commercial items manufactured by Motorola, Inc.*

The base station receiver-transmitter was a Model P43DEN with an FM power output of 10 watts and operated at 150.345 megahertz. The encoder unit allowed selective paging of any one of the 10 receivers. The page signal consisted of a loud tone on the speaker of the selected portable unit. As long as other portables were in the page mode of operation, they were not disturbed by the page signal or the transmissions between base station and the selected portable over the common radio frequency channel. The portable receiver-transmitters (commonly known as "walkie-talkies") were models H23 DEN with an FM radiated power of 2 watts and operated on the same frequency as the base station during both studies.

Operating features, physical dimensions, and weight of the portable units are of some interest in this study. The weight of each portable unit with battery was 40 oz, and the dimensions were 1.812" x 3.375" x 9.187" (56.06 cubic inches). Receiver sensitivity is specified as 0.5 microvolt for 20 db quieting. The portable units were worn on a "Sam Brown" Belt (Model NLN 6352A) and used as external speaker-microphone (Model NMN 6021B) which could be clipped onto the chest strap of the Sam Brown Belt. To use the portable unit to call the base station or to call in response to a page signal, the person wearing the unit had to extend the telescoping style antenna, place the page/talk switch in the talk position, and depress the microphone talk button. The microphone could be left clipped to the chest or removed and hand-held as desired.

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* Other manufacturers' equipments could have been used.

To record the interviews during these studies, a microphone was located to pickup both the voice of the base station operator and the voice reception from the base station receiver. This microphone (furnished with the tape recorder) was connected to a Wollensak tape recorder (Model T-1500) which was equipped with a footswitch to start and stop the tape.

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13. ABSTRACT

Available methods for collecting human factors data rely heavily on observations, interviews, and questionnaires. A need exists for other methods. The feasibility of using two-way voice-radio for this purpose was studied. The data-collection methodology consisted of a human factors analyst talking from a radio base station with technicians wearing portable radio units while they worked on jobs dispersed over an area. Verbal communication probed for information on equipment problems, procedural problems, delays, and potential hazards. The concept of using radio equipment to collect human factors data was tested, using technicians performing flight-line maintenance. Data collected by radio were compared with data collected by questionnaire. It was concluded that voice-radio is not only a feasible means of collecting human factors data in the field, but has certain advantages over questionnaires in determining hardware problems and amplifying the data-collection capability of the human factors analyst.

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